Appendix 1

second "plate," carrying an equal and opposite charge, is a conducting sphere of very large—essentially infinite—radius centered about the conductor. The potential of this infinitely distant sphere, according to the usual convention for potential measurements, is zero. The capacitance of an isolated sphere of radius R is given from Eqs. 30-4 and 30-1 as

$$C = \frac{q}{V} = 4\pi\epsilon_0 R.$$

The mks unit of capacitance that follows from Eq. 30-4 is the coul/volt. A special unit, the *farad*, is used to represent it. It is named in honor of Michael Faraday who, among other contributions, developed the concept of capacitance. Thus

$$1 \text{ farad} = 1 \text{ coul/volt}.$$

The submultiples of the farad, the *microfarad* ($1\ \mu f = 10^{-6}$ farad) and the *micromicrofarad* ($1\ \mu\mu f = 10^{-12}$ farad), are more convenient units in practice.

An analogy can be made between a capacitor carrying a charge q and a rigid container of volume $\mathcal{V}$ containing n moles of an ideal gas.

The gas pressure p is directly proportional to n, for a fixed temperature, according to the ideal gas law (Eq. 23-2)

$$n = \left(\frac{\mathcal{V}}{RT}\right)p.$$

For the capacitor (Eq. 30-4)

$$q = (C)V.$$

Comparison shows that the capacitance of the capacitor, assuming a fixed temperature, is analogous to the volume $\mathcal{V}$ of the container.

Note that any amount of charge can be put on the capacitor, and any mass of gas can be put in the container, up to certain limits. These correspond to electrical breakdown ("arcing over") for the capacitor and to rupture of the walls for the container.

Figure 30-2 shows a more general case of two nearby conductors, which are now permitted to be of any shape, carrying equal and opposite charges. Such an arrangement is called a *capacitor*, the conductors being called *plates*. The equal and opposite charges might be established by connecting the plates momentarily to opposite poles of a battery. The capacitance C of any capacitor is defined from Eq. 30-4 in which we remind the student that V is the *potential difference between the plates* and q is the magnitude of the *charge on either plate;* q must not be taken as the net charge of the capacitor, which is zero. The capacitance of a capacitor depends on the geometry of each plate, their spatial relationship to each other, and the medium in which the plates are immersed. For the present, we take this medium to be a vacuum.

Capacitors are very useful devices, of great interest to physicists and engineers. For example:

1. In this book we stress the importance of *fields* to the understanding of natural phenomena. A capacitor can be used to establish desired electric field configurations for various purposes. In Section 27-5 we described the deflection of an electron beam in a uniform field set up by a capacitor, al-

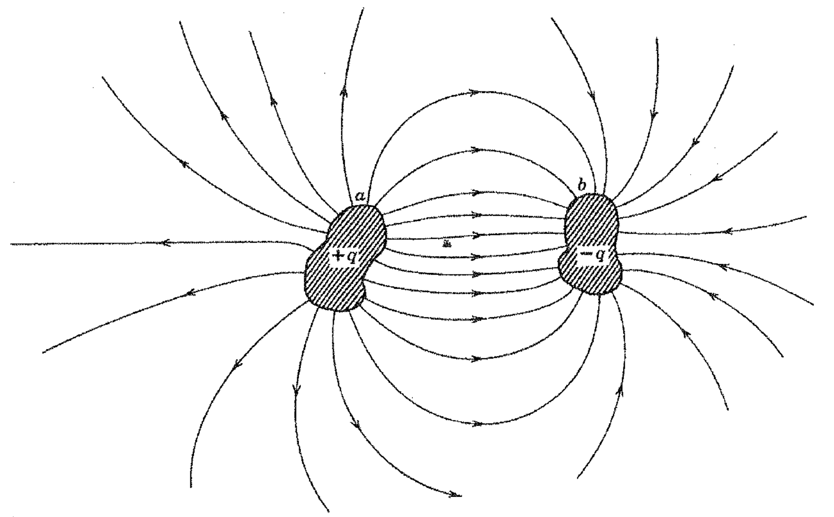

Fig. 30–2 Two insulated conductors carrying equal and opposite charges form a capacitor.

though we did not use this term in that section. In later sections we discuss the behavior of dielectric materials when placed in an electric field (provided conveniently by a capacitor) and we shall see how the laws of electromagnetism can be generalized to take the presence of dielectric bodies more readily into account.

2. A second important concept stressed in this book is *energy*. By analyzing a charged capacitor we show that electric energy may be considered to be stored in the electric field between the plates and indeed in any electric field, however generated. Because capacitors can confine strong electric fields to small volumes, they can serve as useful devices for storing energy. In many electron synchrotrons, which are cyclotron-like devices for accelerating electrons, energy accumulated and stored in a large bank of capacitors over a relatively long period of time is made available intermittently to accelerate the electrons by discharging the capacitor in a much shorter time. Many researches and devices in plasma physics also make use of bursts of energy stored in this way.

3. The electronic age could not exist without capacitors. They are used, in conjunction with other devices, to reduce voltage fluctuations in electronic power supplies, to transmit pulsed signals, to generate or detect electromagnetic oscillations at radio frequencies, and to provide time delays. In most of these applications the potential difference between the plates will not be constant, as we assume in this chapter, but will vary with time, often in a sinusoidal or a pulsed fashion. In later chapters we consider some aspects of the capacitor used as a circuit element.